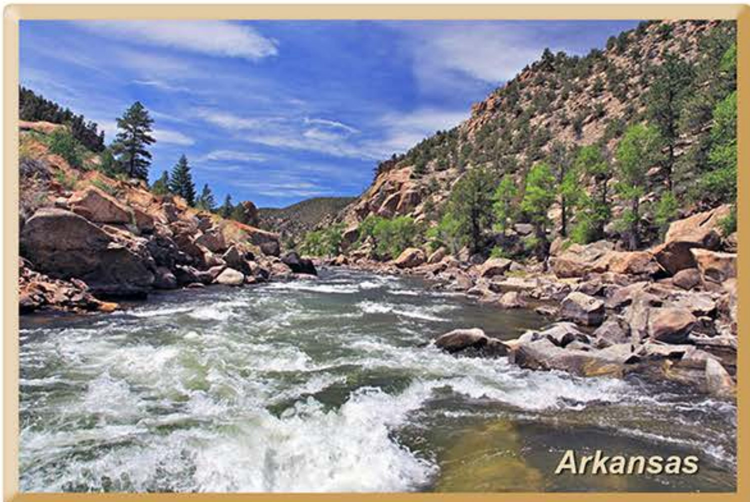
# RECLAMATION

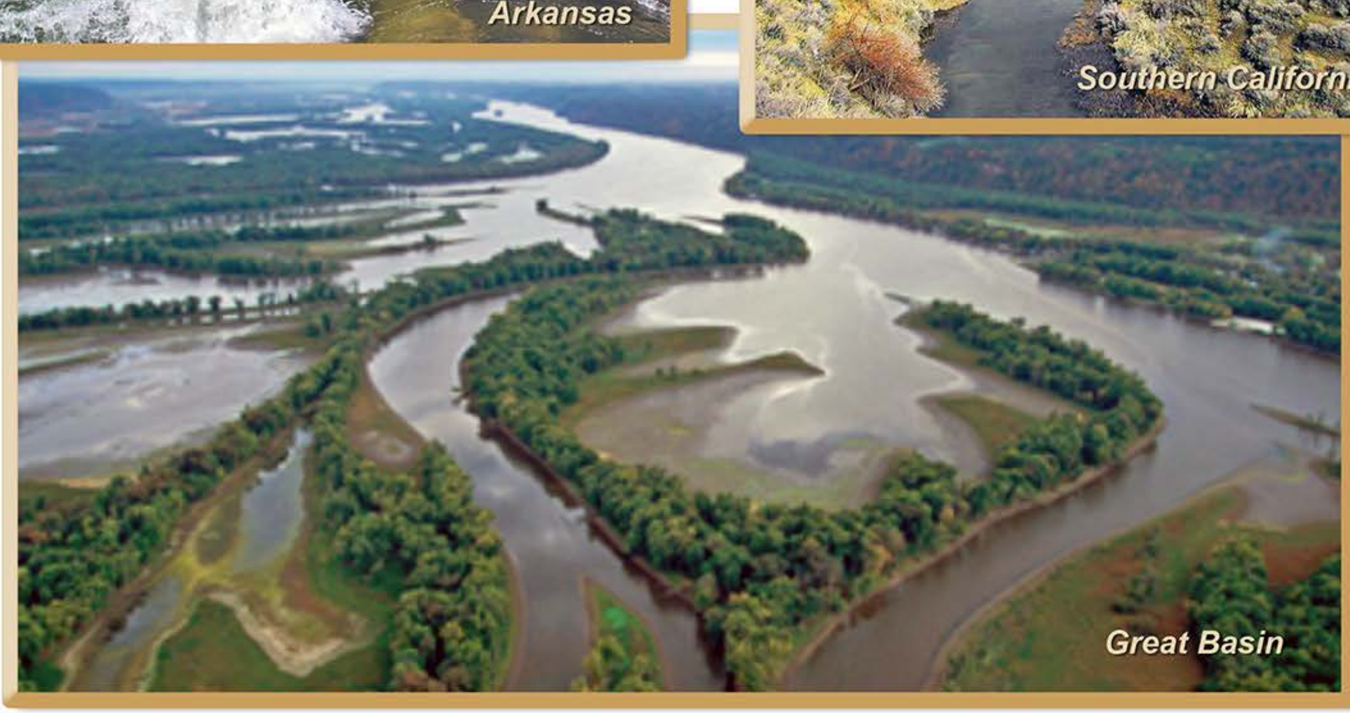
*Managing Water in the West*

**SECURE Water Act Section 9503(c)—Reclamation Climate Change and Water 2016**

# Chapter 10: Other Western River Basins








U.S. Department of the Interior
Bureau of Reclamation

March 2016

# Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

**SECURE Water Act Section 9503(c) Report to Congress**

# Chapter 10: Other Western River Basins

*Prepared for*

**United States Congress**

*Prepared by*

**U.S. Department of the Interior**
**Bureau of Reclamation**

**U.S. Department of the Interior**
**Bureau of Reclamation**
**Policy and Administration**
**Denver, Colorado**

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# Acronyms and Abbreviations

| | |
|---|---|
| °F | degrees Fahrenheit |
| AF | acre-feet |
| AFY | acre-feet per year |
| CUP | Central Utah Project |
| CVWD | Coachella Valley Water District |
| GPCD | gallons per capita per day |
| IID | Imperial Irrigation District |
| LBAO | Lahontan Basin Area Office |
| M&I | municipal and industrial |
| MAF | million acre-feet |
| MCD | Master Conservancy Districts |
| Mitigation Commission | Utah Reclamation Mitigation and Conservation Commission |
| msl | mean sea level |
| MWA | Mojave Water Agency |
| MWD | Metropolitan Water District of Southern California |
| OWRB | Oklahoma Water Resources Board |
| Reclamation | Bureau of Reclamation |
| USACE | U.S. Army Corps of Engineers |
| USGS | U.S. Geological Survey |
| WRWUA | Weber River Water Users Association |
| WaterSMART | Sustain and Manage America’s Resources for Tomorrow |

# About this Chapter

This summary chapter is part of the 2016 SECURE Water Act Report to Congress prepared by the Bureau of Reclamation (Reclamation) in accordance with Section 9503 of the SECURE Water Act. The 2016 SECURE Water Act Report follows and builds on the first SECURE Water Act Report, submitted to Congress in 2011[1], which characterized the impacts of warmer temperatures, changes to precipitation and snowpack, and changes to the timing and quantity of streamflow runoff across the West.

The SECURE Water Act identifies the eight major Reclamation river basins. This chapter provides a summary of activities conducted by Reclamation and its partners in other western river basins not specifically identified in the SECURE Water Act. This chapter is organized as follows:

**Section 1**: Coastal and Inland Basin Areas of Southern California,

**Section 2**: Great Basin, and

**Section 3**: Arkansas-Red-White River Basin

This chapter includes updated information from Reclamation studies completed or initiated in the basin over the past 5 years. The key studies referenced in this chapter include the following:

- Los Angeles Basin Study (ongoing)
- Santa Ana River Watershed Basin Study (completed)
- Mojave River Watershed Climate Change Assessment (completed)
- San Diego Watershed Basin Study (ongoing)
- Southeast California Regional Basin Study (completed)
- Upper Washita Basin Study (ongoing)
- Upper Red River Basin Study (ongoing)

1 The first SECURE Water Act Report, submitted to Congress in 2011 is available on the Reclamation website: www.usbr.gov/climate/secure/docs/2011secure/2011SECUREreport.pdf .

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## Figures

# 1 Southern California Coastal and Inland Basins

Southern California consistently faces serious water supply threats from numerous factors: increasing population, reliance on imported water, flooding, and the overuse of groundwater. Recently, California ranked second among all states in the country for population increases (U.S. Census Bureau, 2011), and as of 2015, the state was struggling through its fourth consecutive year of one of the most severe droughts on record. In a region that experiences highly variable precipitation and periodic drought, climate change may exacerbate shortages in a system already operating on the edge with respect to water supply.

**Coastal and Inland Basin Areas of Southern California**

**States:** California

**California Counties:** Los Angeles, Ventura, Riverside, San Bernardino, and Orange

**Basin Rivers:** Los Angeles River, San Gabriel River, Santa Ana River, Whitewater River, Mojave River, San Diego River, New River, and Alamo River

**Major Water Uses:** Municipal Supply (more than 22 million people), Agricultural irrigation, Flood Control, Recreation, and Fish and Wildlife

## 1.1 Regional Setting

For this chapter, Southern California is separated into two distinct geographical areas: the Coastal Area, which is defined as the Los Angeles, Santa Ana, and San Diego Watershed Basins, and the Inland Basins Area, which is represented by the adjudicated boundary of the Mojave River basin and the Salton Trough region. Figure 10–1 presents the Coastal and Inland Basin Areas, as well as the location of Reclamation Basin Studies.

### 1.1.1 Coastal Area

The Coastal Area encompasses the Southern California watersheds bounded by Malibu to the north and San Ysidro to the south. Most of the water in the area is supplied by the Metropolitan Water District of Southern California (MWD), which provides water to 26 member agencies in a 5,200-square-mile service area that sustains approximately 19 million people.

The area is situated in an arid desert climate without enough local fresh water to support the growing population and major economic development, so it receives approximately 40 percent of its needed water from outside sources. In 2014, 22 percent of the total water supply was provided by the Colorado River (delivered via the 242-mile Colorado River Aqueduct); 17 percent was supplied by northern California (delivered via the 444-mile California Aqueduct); 33 percent was from local supply, which included groundwater, surface water, Los Angeles Aqueduct (from the Sierra Nevada Mountains), and groundwater recovery, and 28 percent of the supply was from conservation and water recycling (Reclamation, 2015 [Moving Forward]).


Figure 10–1. Map of Southern California showing locations of Basin Studies.

**Figure 10–2.  San Diego, California.**
**Source: Reclamation, 2015 (SCAO).**

The metropolitan area population has increased by nearly 50 percent since 1980, adding more than 6 million to the municipal water-service-area population, while total annual water use increased by approximately 20 percent.  On average, per capita water use rates have decreased by approximately 10 percent since 2000. Residential water use accounts for around 70 percent of the total water delivered by MWD (Reclamation, 2015 [Moving Forward]).

In February 2008, Governor Arnold Schwarzenegger introduced a seven-part comprehensive plan for improving the Sacramento-San Joaquin Delta.  As part of this effort, the Governor directed state agencies to develop a plan to reduce statewide per capita urban water use by 20 percent by the year 2020.  This marked the initiation of the 20x2020 Water Conservation Plan (20x2020Plan) process. Because of an unprecedented 4-year drought, Governor Jerry Brown declared a drought State of Emergency in January 2015 and directed state officials to take all necessary actions to prepare for water shortages.  In April 2015, Governor Brown mandated a 25 percent water use reduction for cities and towns across California. For the June-August 2015 period, the cumulative statewide savings rate was 28.7 percent.

Although the majority of water resources within this area are used for urban and agricultural purposes, a variety of wildlife species thrive in southern California's coastal and marine environments, sage scrub and chaparral habitats, and marshes and riparian zones.  Valuable area wetlands, including salt marshes and estuaries, freshwater marshes, riparian woodlands, and a number of reservoirs and lakes are essential resting stops for migrating birds on the Pacific Flyway and provide nesting areas for large numbers of wintering waterfowl (Reclamation, 2015b).

The Coastal Area has a Mediterranean climate with average summer temperatures ranging from 64 to 85 degrees Fahrenheit (°F) during August, the warmest month; average winter temperatures range from 46 to 70 °F during December, the coolest month.  In the inland areas, the climate is semiarid, with colder winters and markedly hotter summers.  Precipitation in the metropolitan area occurs primarily during the winter months and ranges from 10 to 17 inches per year (Reclamation, 2015b).

### 1.1.2 Inland Basins Area

The Inland Basin Area of southeastern California encompasses the Borrego, Coachella, and Imperial Valleys in the Salton Trough region and the high desert region of the Mojave Basin near Barstow, CA. This area includes the cities of Indio, Palm Desert, El Centro, Calexico, Victorville, and Barstow. Both of these areas are water supply limited, and growing municipal and commercial sectors (e.g., retail outlets, resorts, and casinos), a massive agricultural industry, and numerous recent regulatory and legal settlements require a delicate balance to manage existing supply and demand.

Bounded to the east and west by high-elevation mountain ranges that drain to the low-depression valley containing the Salton Sea, the Salton Trough is home to a diverse range of habitats that support more than 1,000 plant species and more than 400 animal species. The Salton Trough region consists of approximately 5,200 square miles and is home to 10 desert cities and four Indian reservations, which have a combined population of 750,000 full-time residents. In addition, millions of winter and spring visitors flock to the Palms Springs and Borrego Springs areas annually. The region is also home to California's largest inland lake, the Salton Sea, which is a critical component of the Pacific flyway. The three irrigation districts that service this vast area have a combined annual agricultural economic value of more than $2.5 billion dollars, and the region's tourism economy generates more than $8.4 billion dollars annually (Reclamation, 2014 [Southeast California]).

The Salton Trough region lies within the Sonoran desert geomorphic area, which has a typical subtropical desert climate—hot summers, mild winters, and 3 to 4 inches of annual precipitation. Temperatures in the summer are often in excess of 120$^{o}$ F. Precipitation falls mainly during the winter months; however, monsoonal summer storms do occur (Reclamation, 2014 [Southeast California]). An estimated 124,000 shorebirds, including at least 25 different species, migrate through the Salton Sea, which is considered the third most important shorebird habitat west of the Rocky Mountains.

The population in the Salton Trough region has almost doubled since 1990, adding more than 230,000 to the municipal water service-area population. Total annual water use increased by approximately 143 percent over the same period. The most recent annual average (2008-2012 average) per capita use was estimated at 314 gallons per capita per day (GPCD). The high per-capita use rates for this metropolitan area are generally associated with large-scale turf irrigation in resort areas Reclamation, 2015 (Moving Forward).

In the Salton trough region, three distinct subareas—Borrego Valley, Coachella Valley, and Imperial Valley—have both unique and overlapping water supply-demand issues. The Borrego subarea is entirely dependent on groundwater. A draft U.S. Geological Survey (USGS) groundwater study (Faunt et al., 2015) of the area indicates the aquifer has an overdraft of 17,000 acre-feet per year (AFY) and estimates that the upper aquifer may be depleted in as little as 50 years. Coachella's challenge is a mix of both groundwater overdraft and Colorado River water supply issues. In addition, a portion of the Coachella subarea's water supply is derived from the State Water Project (SWP) imports and exchanged for

Colorado River water. The Imperial subarea's challenge is near-100-percent dependence on Colorado River water supply (Reclamation, 2014 [Southeast California]).

The Coachella Valley Water District (CVWD) began operation in 1918. It provides service to approximately 1,000 square miles from the San Gorgonio Pass to the Salton Sea, mostly within the Coachella Valley in Riverside County, California. CVWD provides water-related service to more than 303,000 people living in the nine cities of CVWD's service area. CVWD relies on three sources of water (groundwater, recycled water, and imported water) to provide service to its customers, either through the SWP (via exchange) or from the Colorado River via the Coachella Canal, a branch of the All-American Canal. In the CVWD service area, approximately 300,000 AFY of water delivered from the Coachella Canal was initially used exclusively by agriculture. As residential growth moved into the eastern valley, other water users, primarily golf courses and homeowner associations, began using Colorado River water for large landscape irrigation. From 2008 to 2012, more than 40 percent of the total CVWD deliveries were distributed to municipal and industrial (M&I) water users (Reclamation, 2015 [Moving Forward]).

The Imperial Irrigation District (IID), the largest irrigation district in the nation, was formed in 1911 to import and distribute raw Colorado River water, mainly to agricultural irrigation customers. IID delivers an average of 2.8 million acre-feet (AF) of water each year, and 97 percent is used for the irrigation of more than 400,000 acres. In addition, IID supplies water to approximately 178,000 people across seven municipalities. The largest cities included in the IID M&I service area are El Centro and Calexico. The IID diverts water at the Imperial Dam on the Colorado River through the 80-mile-long All-American Canal (Reclamation, 2015 [Moving Forward]).

The Mojave Basin is in the Mojave Desert and is classified as high desert. Elevations within the area range from 1,500 feet mean sea level (msl) in the east to 5,500 feet msl in the mountains to the south. The Mojave Water Agency (MWA) services water users in the adjudicated boundary of the Mojave Basin. Precipitation and runoff throughout the basin are highly variable. Most of the surface water originates from ephemeral streams; consequently, the MWA area has limited surface water supplies. Groundwater supplies are currently used to meet the vast majority of demand. Since groundwater production started in the 1900s, groundwater extraction has greatly expanded, and groundwater levels have been declining since the early 1950s. Since this time, the overdraft has reduced groundwater storage by an estimated 2 million acre-feet (MAF). MWA imports significant amounts of surface water from the SWP (Reclamation, 2013 [Mojave]).

The Colorado River Basin Water Supply and Demand Study (Reclamation, 2012 [CO Basin Study]) assessed historical water supply in the Colorado River Basin, and observations and conclusions of historical temperature and precipitation trends in the Lower Colorado River Basin are consistent with Southern California historical trends. Key findings related to projected changes in temperature, precipitation, snowpack, and runoff are presented below:

- **Increases in temperatures**: Studies consistently show that the temperatures in Southern California will continue to increase. Increases in both minimum and maximum temperatures may be expected, with increases in extreme warm temperatures and decreases in extreme cool temperatures. For the Los Angeles area, a mean temperature increase of 2 to 5 °F is expected by 2050.
- **Decreases in annual precipitation**: Studies suggest that the storm track in the Pacific Ocean may shift northward, resulting in less-frequent precipitation events along the coast of southern California. Changes in mean annual precipitation indicate a mean drying (i.e., less precipitation) of 2 to 5 percent since the mid-20th century, with little additional change by mid-21$^{st}$ century. Additional drying (mean reduction of 2 to 5 percent) could occur along the coastal areas of California.
- **Increases in extreme precipitation events**: Overall, precipitation may be less frequent but more intense, meaning that the contribution to annual precipitation by extreme precipitation events may increase. The heavy rainfall events may be interspersed with longer, relatively dry periods. The higher evaporation rates resulting from the rising temperature may decrease soil moisture, resulting in reduced storm runoff. The literature does not associate a specific return period to extreme precipitation events but rather discusses extreme precipitation events in general terms.

Water demand in the area is expected to increase due to changes in temperature and increased reservoir evaporation (Reclamation, 2013 [Santa Ana]). Key findings related to projected changes in demand are summarized below.

- Overall, there are expected to be two to three times as many extreme days (i.e., greater than 95 °F) in coastal areas and within the Los Angeles Basin. Inland areas were noted to have three to five times the number of extremely hot days (Reclamation, 2013 [Santa Ana]).
- Water demand in the Inland Basins Area is largely dominated by agriculture and, to a lesser extent, municipalities and golf courses. Increased temperatures can affect both agricultural and municipal demand by increasing evaporative demand on crops, golf courses, and lawns. From 1970 to 2003, agricultural demand in the Imperial Valley varied from 2.6 to 3.2 million AFY.
- Projections indicated more winter precipitation and less springtime precipitation. Increased winter precipitation could result in crop damages, and excessive summer heat could decrease yields. In addition, it is expected that as the climate changes, farmers will adapt by changing the types of crops planted, which might also affect demand (Reclamation 2014 [Southeast California]).

- Other drivers influencing demand include the population of the Coastal Southern California Metropolitan Area, which has increased by about 50 percent since 1980, adding more than 6 million to the municipal water service area population, while total annual water use increased by approximately 20 percent.
- Recent averages indicate that residential water use accounts for about 70 percent of the total water delivered by MWD. However, many factors affect future water demands, such as population growth, hydrologic conditions, public education, and economic conditions, among others.
- Municipal demand accounts for only 3 percent of historical Colorado River water deliveries in the Imperial Valley; however, the population is expected to more than double from approximately 162,000 to 365,000 between 2010 and 2050. This level of growth would result in a roughly 64,000-acre increase in urban area (Reclamation 2014 [Southeast California]).
- Since 1999, considerable growth within the Coachella Valley has resulted in the conversion of agricultural and desert lands to residential urban uses. There is a recognized overdraft and a 2002 water management plan set a number of water conservation goals for CVWD in order to reduce demand.
- In the Mojave River Basin, the population is projected to increase nearly 25 percent from 2010 through 2020, and total demand is projected to increase, assuming moderate conservation. For planning purposes, the Mojave Water Agency assumes that average natural water supply and agricultural depletion from storage will remain constant through 2035, while wastewater imports and return flows are projected to increase slightly. SWP imports are projected to increase by approximately 10 percent by 2035 (Reclamation 2013 [Mojave]).

## 1.2 Coordination Activities

The Coastal and Inland Basins Areas of Southern California are situated in an arid desert climate without enough local fresh water to support the growing population and burgeoning economy. As the area receives two-thirds of its needed water supplies from northern California (delivered via the 444-mile California Aqueduct), the Sierra Nevada Mountains (delivered by the 338-mile Los Angeles Aqueduct), and the Colorado River (delivered via the 242-mile Colorado River Aqueduct), water challenges are being addressed through Federal, state, tribal, and local partnerships. Reclamation is an active partner in activities to develop strategies for conservation, water recycling and reuse, salinity management, ground and surface water conjunctive management, storm water augmentation programs, and other watershed management opportunities.

In the Coastal Area, Reclamation has led or participated in multiple studies and activities. Some recent activities include Reclamation's partnership with the Los Angeles and San Gabriel Rivers Watershed Council and other agencies in a Water

Augmentation Study. The purpose of the study is to explore potential adaptation strategies such as reducing urban runoff pollution by increasing infiltration of stormwater runoff. This stormwater infiltration has the potential to augment local groundwater supplies by capturing and recharging stormwater runoff that otherwise would flow unused to the ocean. The Los Angeles Basin Study provides the opportunity for multiple water management agencies to participate in a collaborative process to plan for future local water supply scenarios.

Another example of integrated planning is Reclamation's partnership with the California Energy Commission and the Metropolitan Water District of Southern California to commission an innovative study to bring together energy utilities, water districts, wastewater sanitation districts, and state and local agencies to study the potential for integrated water and energy efficiency programs. This approach allowed water districts and energy utilities to take advantage of opportunities to leverage their limited resources and coordinate resource management efforts to meet future needs (Reclamation, 2015 [SCAO]).

In the Inland Basin Area, Reclamation is also actively involved in conservation initiatives and long-term water management planning. Studies have been conducted in partnership with multiple water agencies and irrigation districts. For example, the Southeast California Regional Basin Study was conducted in partnership with the Borrego Water District and other regional stakeholders. Reclamation also works with the newly created Borrego Water Coalition, which is addressing the significant risks associated with over drafting the Borrego Valley groundwater basin (Reclamation, 2015 [SCAO]).

### 1.2.1 Bureau of Reclamation Partnered Studies

Reclamation administers programs to develop and enhance water management throughout southern California. In cooperation with state and local water agencies, Reclamation programs address desalination research, conjunctive use of ground and surface water resources, stormwater runoff augmentation, watershed modeling that addresses both water quantity and quality, and the development of new water resources. Recent activities include long-term planning focused on options to provide water management assistance to address complex water issues on local, regional, and statewide levels, as well as water conservation-related projects through WaterSMART Grants to facilitate water conservation and efficiency improvements on Federal and non-Federal projects (Reclamation, 2015 [SCAO]). Recent and on-going Reclamation studies with partners in the Coastal and Inland Basin Areas include the following:

- **Colorado River Basin Water Supply and Demand Study**: Completed in 2012, the study evaluated future water supply and demand in the Colorado River Basin and adjacent areas receiving Colorado River water, including the Coastal and Inland Basin Areas (Reclamation, 2012 [CO Basin Study]).
- **Santa Ana Watershed Basin Study**: Completed in 2013, the study focuses on the Santa Ana Watershed Project Authority's integrated regional water

resources planning process, refined the region's water projections, and identified potential strategies to help the region adapt to climate change (Reclamation, 2013 [Santa Ana] and Reclamation, 2013 [Santa Ana Summary]).

- **Mojave River Watershed Climate Change Assessment**: Completed in 2013, this report provides a detailed climate change assessment of the Mojave River watershed (Reclamation, 2013 [Mojave]).
- **Los Angeles Basin Study**: Reclamation is collaborating with the Los Angeles County Flood Control District for this ongoing, phased effort investigating long-term water conservation and flood-control impacts from projected climate conditions and population changes in the Los Angeles Basin. This study is expected to be completed in 2016.
- **San Diego Watershed Basin Study** – This study, expected to be completed in 2016, will assess the San Diego region's water supply and demand and determine the potential effects from climate change impacts within the San Diego Integrated Regional Water Management planning region. It will also analyze the region's existing infrastructure and develop adaptation strategies that can assist with addressing the uncertainties associated with climate change.
- **Southeast California Regional Basin Study**: Completed in 2014, the study addressed current and future supply and demand imbalances in the Coachella, Borrego, and Imperial Valleys of California, provided an assessment of existing infrastructure resources, and developed options and alternatives to solve identified issues and help plan for an uncertain water supply future (Reclamation, 2014 [Southeast California]).
- **Colorado River Basin Study *Moving Forward* Effort**: The Colorado River Basin Study was widely described as a "call to action." In May 2013, the Department of the Interior and other stakeholders launched the *Moving Forward* effort to identify and implement, in a coordinated and collaborative manner, actions to address projected supply and demand imbalances that have broad-based support and provide a wide range of benefits. In Phase 1 of the effort, completed in 2015, three workgroups focused on water-use efficiency (urban and agricultural) and environmental and recreational flows throughout the Basin, including the Coastal and Inland Basins Areas (Reclamation, 2015 [Moving Forward]).

Reclamation basin studies and other planning efforts have demonstrated that the implementation of a broad range of options can help improve the Coastal and Inland Basins Areas' resiliency to dry and variable hydrologic conditions. Actions to help ensure the sustainability of these areas are occurring at a variety of scales and locations, ranging from basin-wide initiatives to specific infrastructure improvements.

# 2 Great Basin

The Great Basin includes most of Nevada, western Utah, and small portions of bordering states, including Wyoming, Idaho, Oregon, and California. The southern boundary is less distinct. The Great Basin region has a population of roughly 3.2 million people. Major population centers include Salt Lake City, Utah, and Reno, Nevada, and the region is sparsely populated outside of the two major cities. Water uses include hydropower, irrigation, recreation, fish and wildlife, and municipal and industrial water supply.

| Great Basin Setting |
| --- |
| **States:** California, Idaho, Nevada, and Utah |
| **Major U.S. Cities:** Salt Lake City, Ogden, Reno, and Carson City |
| **Longest River Length:** 350 miles (Bear River) |
| **River Basin Area:** 140,000 square miles |
| **Major River Uses:** Municipal (6 million people), Agricultural, Flood Control, Navigation, and Recreation, and Ecological Uses |
| **Reclamation Irrigation Projects in the Great Basin:** Central Utah Project (Bonneville, Jensen, and Vernal Units), Humboldt Project, Hyrum, Newlands Project, Newton, Ogden River, Preston Bench, Provo River, Strawberry Valley, Truckee River Storage Project, Washoe Project, Weber Basin, and Weber River |

## 2.1 Great Basin Setting

The Great Basin region consists of many small basins that together span an area of roughly 140,000 square miles. The region includes the Bear River, Great Salt Lake, Escalante Desert-Sevier Lake, Central Lahontan, and Central Nevada Desert Basins, and the Black Rock Desert-Humboldt subbasins. The Great Basin's longest (350 miles) and largest river is the Bear River in northern Utah; the largest single watershed is the Humboldt River drainage in north-central Nevada (17,000 square miles). Lake Tahoe, North America's largest alpine lake, is part of Great Basin's Central Lahontan subbasin.

The region is bounded by the Wasatch Mountains to the east, the Sierra Nevada Mountains to the west, and the Snake River Plain to the north (Figure 10–3). The Great Basin is a closed basin, with no drainage to the Pacific Ocean or the Gulf of Mexico. All precipitation in the region evaporates, sinks underground, or flows into lakes, most of which are saline. The Great Salt Lake, Pyramid Lake, and the Humboldt Sink are a few of the drains in the Great Basin.

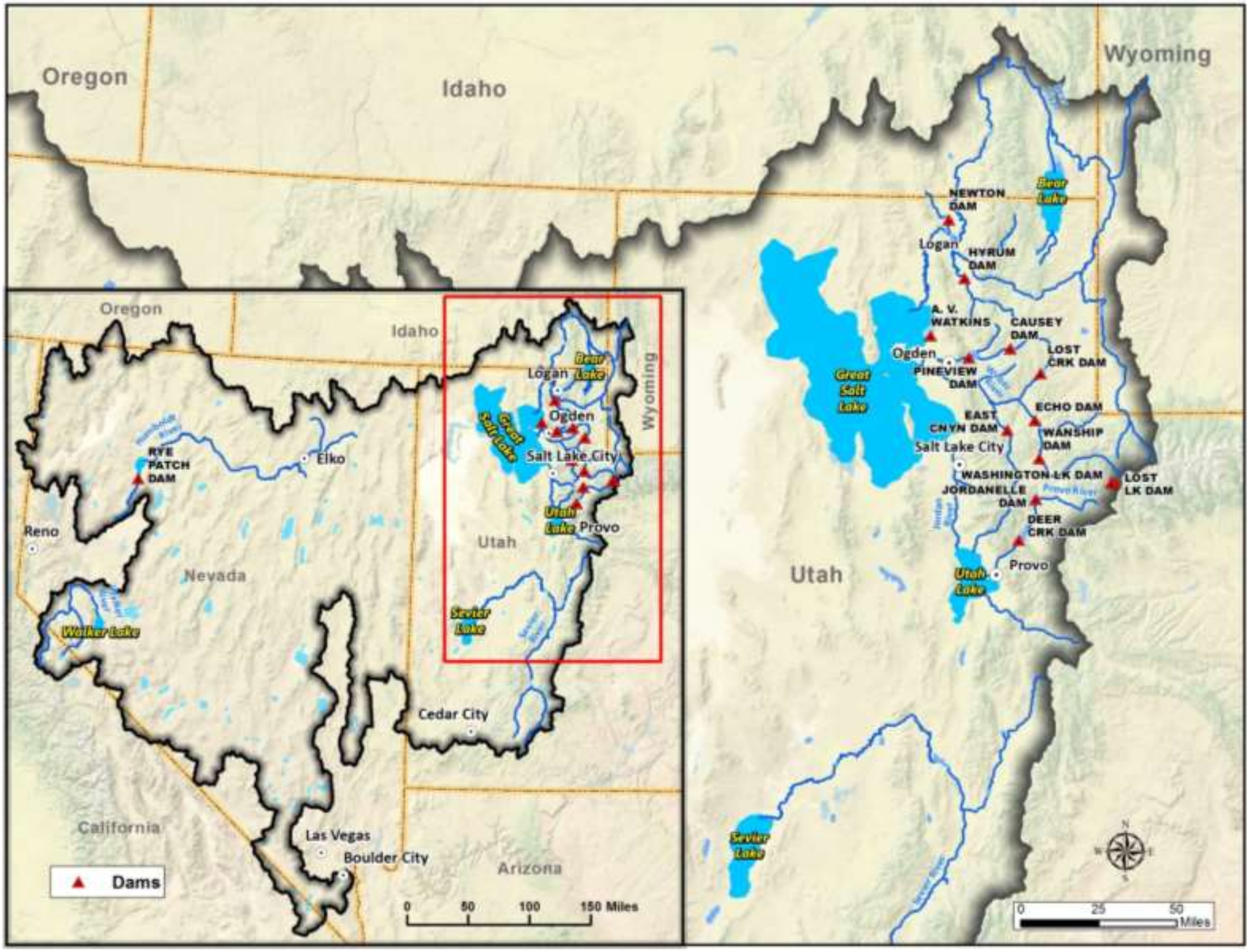


Figure 10–3.  Map of the Great Basin.

Public and private development of the water resources of the Great Basin has resulted in the addition of many features for flood control, irrigation, hydroelectric power generation, recreation, improvement of fish and wildlife habitat, and municipal and industrial water supply. Most of the Federally directed water resources development in the basin has been undertaken by Reclamation. The Sacramento District of the U.S. Army USACE of Engineers (USACE) is involved in the management of some of these federal facilities. Reclamation has constructed thirteen irrigation projects in the Great Basin. Nine of these projects are administered by the Provo Area Office of the Upper Colorado Region, including:

- Central Utah Project (Bonneville, Jensen, and Vernal Units)
- Hyrum
- Newton
- Ogden River
- Preston Bench
- Provo River
- Strawberry Valley
- Weber Basin
- Weber River

The Central Utah, Provo River, and Strawberry Valley projects also utilize trans-basin diversions from the Green River system (a tributary to the Colorado River) to the Great Basin for project water supplies.

Reclamation's Lahontan Basin Area Office (LBAO) of the Mid-Pacific Region also has jurisdiction over a large area of the Great Basin, including most of the northern two-thirds of Nevada, with a small amount of overlap into California and Oregon. The main area of LBAO activities is in the Carson, Truckee, and Humboldt River basins, where there are four operating Reclamation projects:[2]

- Newlands Project
- Truckee River Storage Project
- Washoe Project
- Humboldt Project

Climate varies throughout the Great Basin by elevation, latitude, and other factors. Much of the Great Basin is characterized by a semi-arid or arid climate and by basin-and-range topography. Elevation in the region ranges from 283 feet below sea level, the lowest point in North America, to 14,505 feet less than 100 miles away at the summit of Mount Whitney, which is the highest point of the

[2] Note: Chapter 9: Truckee River Basin Summary includes specific information on the Truckee River Basin setting, implications for various water and environmental resources, adaptation strategies, and coordination activities.

contiguous United States. The western areas of the basin tend to be drier than the eastern areas because of the rain shadow of the Sierra Nevada. Higher elevations tend to be cooler and receive more precipitation, with most Great Basin precipitation falling as snow. Average annual rainfall ranges from 1.5 inches in Death Valley to 40 inches in the Wasatch Mountains. Because of snowmelt processes, natural streamflow is historically highest in the late spring and early summer and diminishes rapidly by mid-summer. While flows in late summer through autumn sometimes increase following rain events, natural streamflow in the late summer through winter is generally low compared to spring and early summer. Key generalizations related to projected changes in temperature, precipitation, snowpack, and runoff are presented below:

- **Temperature** is projected to increase approximately 2.7 to 8.1 °F by the latter half of the 21$^{st}$ century for the Great Basin region. The largest increases are projected for the summer months. Reasonable consensus is also seen in the literature with respect to projected increases in extreme temperature events, including more frequent, longer, and more intense summer heat waves in the long-term future compared to the recent past (USACE, 2015).
- **Precipitation** projections in the study basin are less certain than projections associated with air temperature. Results of the studies reviewed here are roughly evenly split with respect to projected increases versus decreases in future annual precipitation. There is, however, moderate consensus among the reviewed studies that future storm events in the region will become more intense and more frequent compared to the recent past (USACE, 2015).
- **Streamflow** projections are variable. In some cases, models indicate minimal change in future streamflow, but in other cases indicate a potential increase in runoff and/or streamflow in the Great Basin region (USACE, 2015).

Potential climate change impacts on agricultural, municipal and industrial, and in-stream water demands are difficult to predict, and existing information on the subject is limited. It is widely accepted that water demands will change due to increased air temperatures; increased atmospheric carbon dioxide levels; and changes in precipitation, winds, humidity, and atmospheric aerosol and ozone levels. Furthermore, these natural-system changes must be considered in combination with socioeconomic changes, including infrastructure, land use, technology, and human behavior. Key projections related to changes in demand are summarized below.

- Agricultural irrigation is the predominant water demand in the Great Basin and throughout the greater western United States (Frederick, 2001). The seasonal volume of agricultural water demand could increase if growing seasons become longer, assuming that farmers could adapt to this opportunity by planting more crop cycles per growing season.

- Additionally, agricultural water demand could decrease due to crop failures caused by changes in pests and diseases in the future.
- In addition to changes in water demands associated with natural processes, which are difficult to quantify, municipal and industrial consumption is projected to increase due to population growth.
- Domestic water use is not very sensitive to changes in temperature and precipitation (Frederick, 2001), and water conservation measures may reduce potential increases in per capita water usage, thereby offsetting potential increase in population.
- Climate change also could result in changed demands for in-stream flows or reservoir releases to satisfy other system objectives, including ecosystem support, hydropower generation, municipal and industrial water deliveries, river and reservoir navigation, and recreational uses.
- Water demands for endangered species and other fish and wildlife could increase with ecosystem impacts due to warmer air and water temperatures and resulting hydrologic impacts (e.g., runoff timing).
- Diversions and consumptive use by industrial cooling facilities are predicted to increase, since these processes will function less efficiently with warmer air and water temperatures. The timing of these diversions and those for hydropower production also could be a factor in ecosystem demands and navigation and recreational water uses.

As climate change might affect water supplies and reservoir operations, the resultant effects on water allocations from year to year could increase pressure for water uses (e.g., crop types, cropping dates, environmental flow targets, transfers among different uses, hydropower production, and recreation). Such climate-related changes in water use would interact with market influences on agribusiness and energy management, demographics, land use changes, and other non-climate factors.

## 2.2 Coordination Activities

Interest in ensuring the sustainability of water resources in the Great Basin is broad and includes Federal, state, and local governments, tribes, agricultural users, purveyors of M&I water, power users, and conservation and recreation groups. Water management in the basin is complex, as are the challenges associated with balancing competing needs such as water delivery, hydropower generation, and environmental protection. To meet such challenges, various stakeholders have implemented programs and initiatives, each with its own set of goals, objectives, approaches, and processes, in various parts of the basin. These stakeholders recognize that cross-program coordination and information exchange are important strategies that can allow such programs to work together and focus resources to address basin-wide challenges.

### 2.2.1 Utah Reclamation Mitigation and Conservation Commission

The Utah Reclamation Mitigation and Conservation Commission (Mitigation Commission) is a Federal agency authorized under the Central Utah Project (CUP) Completion Act of 1992. The Act set terms and conditions for completing the Central Utah Project, which diverts, stores, and delivers large quantities of water from numerous Utah rivers to meet the needs of central Utah's citizens. The Mitigation Commission is responsible for designing, funding, and implementing projects to offset the impacts to fish, wildlife, and related recreation resources caused by CUP and other Federal water management projects in Utah.

Many mitigation projects require completing efforts initially administered by Reclamation and the Department of the Interior, now two of the Mitigation Commission's most important partners. Under the Mitigation Commission's umbrella authority, other Federal and Utah state agencies, local governments, universities, non-profit organizations, and the Ute Tribe cooperate through agreements with the Mitigation Commission to implement a wide variety of ecosystem restoration and wildlife conservation projects in Utah, including:

- Diversion dam modifications
- Provo River Restoration Project
- Angler access
- Wetland preservation and restoration
- Aquatic and riparian habitat restoration
- Native species recovery and sensitive species inventory
- June Sucker Recovery Implementation Program

Annual funding for Mitigation Commission projects depends on Congressional appropriations through the Secretary of the Interior as part of the Department of the Interior's Central Utah Project Completion program.

### 2.2.2 Weber River Collaboration

#### *2.2.2.1 Weber River Management Plan*

This Weber River Water Management Plan was prepared for the Weber River Water Users Association (WRWUA) with partial funding from a Reclamation Water Conservation Field Services Program grant. Cost share partners include WRWUA, Weber Basin Water Conservancy District, Davis and Weber Counties Canal Company, and the Weber River Water Rights Committee. Several other private, state, and Federal entities were also involved during the preparation of the Management Plan.

The Weber River and its tributaries are the sole source of water for three Reclamation projects (Weber River, Ogden River, and Weber Basin Projects), and a contributing source for a fourth (Provo River Project). Numerous other private developments also depend on the Weber River for water. Population in the Weber River basin area has increased significantly in the several decades since these projects were constructed. This growth is expected to continue into the future, placing increasing demands on the limited water supply. Because of the importance of the Weber River to the multiple agricultural, municipal, industrial, power, recreational, and environmental interests in the area, effective water management and planning are critical needs.

The Management Plan was prepared to provide a database of information related to the management and operation of the Weber River system, to describe the current operations of the major projects and facilities on the Weber River, and to identify and adopt measures for improving the management of the system.

#### 2.2.2.2 *Weber River Symposium*

The Weber River is a valuable watershed to the people of Utah. It has shaped the charismatic landscape of northern Utah and it is the primary source of water for drinking, irrigation, recreation, and industrial uses. The Weber River also provides recreational opportunities, fish and wildlife habitat, and the cornerstone for current and future economic development. Over the past year, individuals representing cities, counties, water users, conservation districts, and private/state/Federal agencies have collaborated to establish the Weber River Partnership and a restoration framework through the development of a Weber River Watershed Plan. In conjunction with the plan, the Partnership established an annual forum where stakeholders can gather to discuss major conservation efforts, challenges, and realities throughout the watershed.

The Weber River Symposium is designed to bring together stakeholders with an interest in the Weber River, and to develop and strengthen partnerships. The inaugural Weber River Symposium was a 2-day event held in Ogden, Utah, in November 2014. The event was well attended by Federal, state, and local water managers, including Reclamation, as well as local officials and the public. Ogden City Mayor Mike Caldwell was the keynote speaker for the symposium.

### 2.2.3 Science and Technology Research

Since 2013, Reclamation's Research and Development Office has provided funding through its Science and Technology Program to investigate climate change and variability impacts to water resources along the Wasatch Front. In one study, researchers are studying whether tree rings from local species can provide longer records of climate impacts for better future planning (Liljegren, 2013). City planners and others in the Wasatch Front area of Utah could utilize the results to determine previous climate impacts and forecast supplies in the future. Collaborators include Utah State University, Columbia University's Lamont-Doherty Earth Observatory, Brigham Young University, and various Irrigation Districts.

In 2014 and 2015, Reclamation's Research and Development Office also provided funding through its Science and Technology Program to investigate infrequent large groundwater recharge events and their importance for long-term groundwater availability, use, and management. This research was conducted in collaboration with the USGS Utah Water Science Center to address the information gap of climate change effects on groundwater and the resultant impacts to surface-water supply over the next several decades. This study assisted Reclamation in developing a methodology that could be applied drainage-basin by drainage-basin across the western United States. The assessment method consistently provides information about the relative importance of groundwater in support of basin-specific surface-water flow and illustrates how changing climate conditions (i.e., changes in groundwater recharge) might affect future stream-flow volumes in these drainage basins.

# 3 Arkansas-Red-White River Basin

The Arkansas-Red-White River Basin encompasses the entire state of Oklahoma and portions of Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, and Texas. The three basins (the Arkansas, Red, and White River Basins) drain about 280,000 square miles involving all or parts of eight states, 331 counties, and 28 congressional districts.

| Arkansas-Red-White River Basin Setting |
| --- |
| **States:** Arkansas, Colorado, Kansas, Louisiana, Missouri, New Mexico, Oklahoma, and Texas |
| **Major U.S. Cities:** Little Rock, Pueblo, Wichita, Springfield, Oklahoma City, Tulsa, Amarillo, and Wichita Falls |
| **River Length:** 1,500 miles |
| **River Basin Area:** 280,000 square miles |
| **Major River Uses:** Municipal (6 million people), Agricultural, Flood Control, Navigation, Recreation, and Ecological Uses |
| **Key Studies Referenced in this Report:** Upper Red River Basin Study and Upper Washita Basin Study |

## 3.1 Basin Setting

Water uses in the basin include navigation, hydropower, irrigation, recreation, fish and wildlife, and municipal and industrial water supply. The region has a population of about 6 million and includes the following metropolitan areas:

- Fort Smith and Little Rock, Arkansas
- Pueblo, Colorado
- Dodge City and Wichita, Kansas
- Shreveport and Alexandria, Louisiana
- Tucumcari, New Mexico
- Springfield and Joplin, Missouri
- Oklahoma City and Tulsa, Oklahoma
- Amarillo and Wichita Falls, Texas

Public and private development of the water resources of the Arkansas, Red, and White River basins has resulted in the addition of many features for flood control, navigation, irrigation, generation of hydroelectric power, recreation, improvement of fish and wildlife habitat, and municipal and industrial water supply. Most of the Federally directed water resources development in these basins has been undertaken by the USACE. Reclamation has constructed only three irrigation projects in the Arkansas-Red-White River basins.

### Arkansas River

The headwaters of the Arkansas River are fed by snowpack from the Sawatch Range of the Rocky Mountains near Leadville, Colorado. From its headwaters, the Arkansas River flows 1,460 miles through Kansas, Oklahoma, and Arkansas to its confluence with the Mississippi river near Arkansas City, Arkansas. The Arkansas River drainage basin covers nearly 161,000 square miles.

### White River

The White River forms in the Boston Mountains of northwest Arkansas and flows for 722 miles to the Mississippi River in Desha County, Arkansas. The White River drains a watershed of 17.8 million acres across 60 counties in two states, Arkansas and Missouri.

### Red River

The Red River is a major tributary of the Mississippi and Atchafalaya Rivers. It is formed by two branches, both originating in the Texas panhandle. The larger, southern fork, known as the Prairie Dog Town Fork, begins in Randall County, Texas. The smaller, northern fork, known as the North Fork, begins near Pampa, Texas, and flows eastward and then southward until it joins with the Prairie Dog Town Fork along the Texas-Oklahoma border. Combined, the two forks form the main stem of the Red River. The Red River's total length is 1,360 miles and its watershed covers 65,590 square miles throughout Arkansas, Louisiana, Texas, and Oklahoma, making it the second largest river basin in the southern Great Plains. The Red River Basin receives little precipitation, and flows can be intermittent in the portions above Arkansas. The basin's flat, fertile agricultural land is supported largely through groundwater.

## 3.2 Coordination Activities

Reclamation has recently initiated two Basin Studies in the Arkansas-Red-White River basin, the Upper Washita Basin Study and the Upper Red River Basin Study, which are described below (Figure 10–4).

### Upper Washita Basin Study

Reclamation is collaborating with the Oklahoma Water Resources Board (OWRB), in partnership with the Foss and Fort Cobb Reservoir Master Conservancy Districts (MCD), to evaluate water management issues in the Upper Washita River Basin in west-central Oklahoma. The study area comprises more than 5,000 square miles of drainage area in west-central Oklahoma, along with the Texas panhandle. The area of study includes the Rush Springs aquifer, a critical agricultural supply source that supplies many springs and streams and provides unique environmental, recreational, and cultural values to the area. Reclamation's Washita Basin Project, composed of both Foss and Fort Cobb Reservoirs, provides 90 percent of the surface water supplies in the study area, including municipal water to 40,000 people and two power generation facilities.

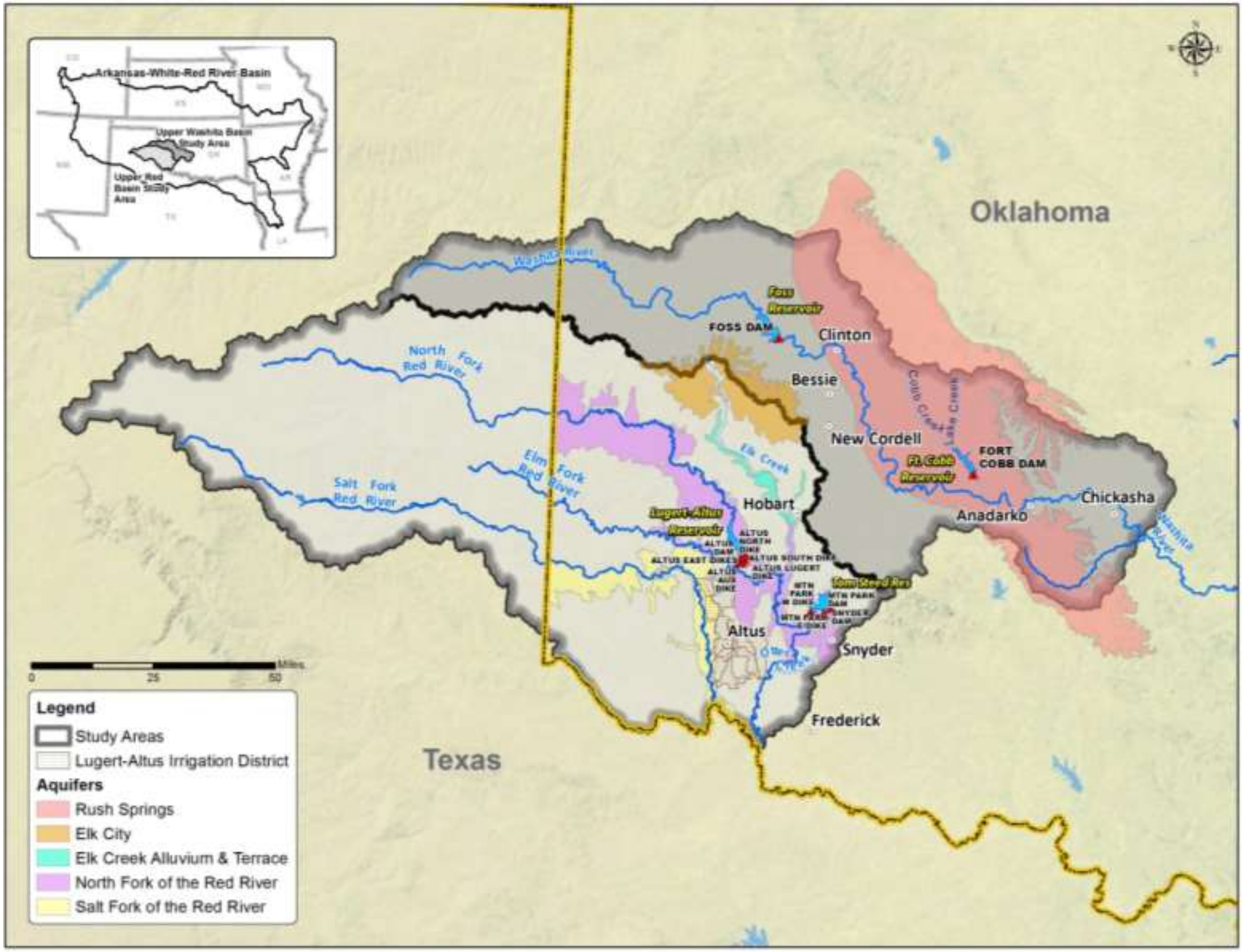


**Figure 10–4. Location of on-going basin studies in the Arkansas-Red-White River Basin.**

Both reservoirs are currently experiencing challenges due to aging, inefficient, and/or undersized infrastructure. Fort Cobb Reservoir MCD, for instance, has been unable to meet peak water demands for up to 4 months every year for the past 12 years due to an undersized and inefficient aqueduct system; Foss Reservoir MCD is having trouble meeting the immediate needs of its member cities due to the limited capacity of its treatment plant. Long-term supply reliability is also a challenge.

According to the recently completed 2012 Oklahoma Comprehensive Water Plan, demands are projected to increase substantially by 2060 for all uses in the study area. Under current permitting procedures, depletions in the Rush Springs aquifer are forecast throughout much of the study area by 2020. These depletions may reduce flows of Cobb Creek, which contributes to Fort Cobb reservoir's firm yield, and therefore threaten the reliability of Fort Cobb reservoir as a supply source. Also of concern are whether climate-related changes in precipitation, run-off and evaporation rates may affect aquifer recharge and reservoir yield.

The Upper Washita Basin Study, which is expected to be completed in 2016, will:

- Characterize and quantify surface and groundwater resources;
- Develop a surface water allocation model to evaluate various water management options, including protecting the future water supply capabilities of Foss and Fort Cobb reservoirs;
- Assess operational and infrastructure constraints associated with Foss and Fort Cobb reservoirs; and
- Evaluate alternatives to address water supply issues facing the study area, both now and in the future.

## Upper Red River Basin Study

Reclamation is collaborating with the Oklahoma Water Resources Board (OWRB), in partnership with Lugert-Altus Irrigation District and Mountain Park Master Conservancy District to evaluate water management issues in the Upper Red River Basin in southwest Oklahoma. The Upper Red River Basin encompasses more than 4,000 square miles and all or part of nine counties in southwest Oklahoma. The region includes tributaries to the Red River, the largest being the North Fork, the Salt Fork, and the Elm Fork of the Red River. The basin contains two Reclamation reservoirs, Lugert-Altus and Tom Steed Reservoirs. These two reservoirs provide 99 percent of the surface water supply sources in the study area to almost 45,000 people and irrigation water for 48,000 acres of land.

The water supply needs in the study area are both immediate and severe due to water quantity and quality issues, as well as aging infrastructure. An extreme drought has stricken the area since 2011, and both Lugert-Altus and Tom Steed Reservoirs are at record lows. A large portion of the study area remains in exceptional drought. Groundwater depletions in the area are forecasted to be as high as 17,220 acre-feet per year by 2060, resulting in increased likelihood of localized impacts and potential effects on streamflow.

Additionally, the 2012 Oklahoma Comprehensive Water Plan Update analysis identified six of the twelve subbasins within the study areas that have been forecasted to face significant water supply challenges within the next 50 years. These challenges prompted stakeholders to develop a Southwest Oklahoma Water Supply Action Plan (May 2014) that outlines short-, mid-, and long-term solutions in the area. Using the Southwest Action Plan as a guide, the Upper Red River Basin Study, which is expected to be completed in 2018, will:

- Characterize and quantify surface and groundwater resources;
- Conduct hydrologic investigations on the North Fork of the Red River Alluvium and Terrace, Elk City Sandstone, and Salt Fork of the Red River Alluvium and Terrace to determine the amount of groundwater available for future appropriations;
- Develop a surface water allocation model to evaluate water management options, including protecting the future water supply capabilities of Lugert-Altus and Tom Steed Reservoirs;
- Assess current and future capabilities to meet demands, including operational risks and reliability of the system; and
- Evaluate alternatives to address water supply issues facing the study area, both now and in the future.

In addition to the Basin Study efforts, the USGS will work in collaboration with Reclamation on the Red River Basin Focus Area Study. The USGS will develop products that can support Bureau of Reclamation project that will include: (1) basin-wide water-use data by category (such as municipal, agricultural, and domestic); (2) a groundwater model upstream of the Denison Dam on Lake Texoma to quantify groundwater/surface-water interactions and effects of climate change and increased groundwater withdrawals; (3) expand an existing daily time-step Precipitation Runoff Modeling System model of natural streamflows for the entire Red River Basin, augmenting an ongoing project with the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative downstream of Lake Texoma; and, (4) an evaluation of future changes to fish assemblages due to changes in flow regime.

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